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ABSTRACT

One of twelve water treatment technology units, this student manual on flouridation provides instructional materials for three competencies. (The twelve units are designed for a continuing education training course for public water supply operators.) The competencies focus on the following areas: purpose and process of flouridation, correct flouride dosage, and proper measurement and handling techniques for flouride chemicals. For each competency, student objectives, resources (information sheets and appendix materials), learning activities, and evaluation activities are provided. The appendices contain information sheets on flouridation of public water supplies and laboratory equipment and supply requirements for a small water treatment plant providing complete treatment. Generally, an evaluation form with answer key is provided for each competency. (JH)

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Water Treatment Technology

FLUORIDATION

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December, 1978

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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CE 022 322

FLUORIDATION

EVALUATOR'S COPY

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EVALUATOR'S INSTRUCTIONS

Name _____

Address _____

_____

Phone _____

This is your EVALUATOR'S COPY of the FLUORIDATION unit. It contains all of the materials received by the operators who will be working on the unit. It also contains *answer keys* and *directions* for the evaluation of each competency. For each Competency Sheet, there is a COMPETENCY, a list of RESOURCES, LEARNING ACTIVITIES, and EVALUATION ACTIVITIES.

Your student operators will call you when they are ready to be evaluated. An operator may complete the evaluations in *any* order. S/he may choose to complete one at a time, or several at one time. *It is up to you and each operator to set convenient schedules for the evaluations.* It is important that the operators learn the skills listed in each competency. It is <u>your</u> job to be sure the operators can perform the competencies.

If an operator does <u>not</u> complete an evaluation correctly, s/he may try again later after practicing the skills. It would be helpful for you to tell the operators just how they should improve their knowledge and skills in order to complete the evaluation successfully. Be sure to call if you have any questions.

This package contains:

- - - - - FLUORIDATION unit

- - - - - Evaluation Forms for each Competency

You will receive instructions as to where to send the completed evaluation forms. Please be sure that the operator's name and your name are on the forms, as well as the date on which the evaluation was performed.

INSTRUCTIONS FOR THE STUDENT OPERATOR

The FLUORIDATION unit contains three competencies. A "competency" is a skill that is necessary for good on-the-job performance. Each competency in this unit is necessary for you to perform on the job according to the West Virginia Department of Health. There is a Competency Sheet to help you understand each competency.

DIRECTIONS FOR COMPLETING THE UNIT:

1. Read each Competency Sheet carefully. Every Competency Sheet contains:

   COMPETENCY
   Objectives
   RESOURCES
   LEARNING ACTIVITIES
   EVALUATION ACTIVITY(IES)

2. After reading the whole Competency Sheet, you should understand what will be expected of you.

3. Do the LEARNING ACTIVITIES that you think will help you the most. This may include reading some of the RESOURCES which have been included with the unit.

4. If you need additional help, ask an operator in your plant for assistance, or call your evaluator; he's there to help you.

5. When you are ready to complete the EVALUATION ACTIVITY for one or more competencies--call your evaluator. The two of you will schedule the best time for your evaluation.

   a. If you complete the evaluation correctly, go on to the next competency.
   b. If you do <u>not</u> complete the evaluation correctly, your evaluator will tell you what your mistakes were. You must go back and practice your skills and read the RESOURCES again. Call your evaluator when you are ready to try again. *You must wait at least one week before being re-evaluated on a competency.*

6. When you complete all your evaluations correctly you will receive a Certificate of Accomplishment and 0.6 Continuing Education Units of Credit.

7. If you want to go on to another unit, contact your evaluator for the materials. The procedure will be similar for all units.

AN EXPLANATION OF CONTINUING EDUCATION UNITS

For student operators in the OPERATOR-IN-TRAINING category who will be taking the certification examination for Class I, this course is an opportunity to increase your knowledge and competence in the treatment of water for human consumption. Successful completion of the manuals will also, it is hoped, make passing the certification exam much easier. The Continuing Education Units which you will get by taking this course will not decrease the minimum one year operating experience requirement for a Class I certificate.

For student operators who now hold a Class I certificate, the completion of all twelve manuals in the course will reduce the currently required three years of total operating experience for Class II certification by approximately four months. Thus, if you complete the course, you will need only two years and eight months of total operating experience before you take the Class II exam.

Here is a listing of the Continuing Education Unit (CEU) value of each of the manuals.

Manual	CEU Value
General Plant Operation	1.4
Taste, Odor, and Color	0.6
Chemistry/Bacteriology	2.5
Chlorination	2.5
Fluoridation	0.6
Filtration	1.2
Hydraulics	0.6
Distribution Systems	1.2
Pumps	0.6
Wells	1.0
Cross Connections	0.4
Springs	0.4
Total	13.0

For comparison with other types of training previously available, the CEU conversions below are given.

Public Water Supply Operator's Short Course (given by State Department of Health Personnel)	4 CEUs
One Semester Hour of College Credit	1.5 CEUs
One Year of College Credits (30 semester hours)	45 CEUs

COMPETENCY: Describe the purpose and process of fluoridating water.

Objective: Describe the specific advantages of fluoridated water.

Objective: Describe the various ways in which fluoride may be added to water.

RESOURCES:

(a) Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 15, 1968, pp. 182-190. *-Blue Appendix-*

(b) Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter XXII. *-Yellow Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about the purpose and process of fluoridating water.

(b) Observe an experienced water treatment operator perform the procedures necessary to properly fluoridate water. Make note of the amount of fluoride required, the fluoride chemical used, the type of feeder, and the point of application.

EVALUATION ACTIVITY: Complete Evaluation Form #32. It contains questions about the purpose and process of fluoridating water. You may not use references.

Operator _____

Evaluator _____

Date _____

Directions: Write the word "True" or "False" in the space provided next to each item. If you answer "False" write the correct answer on the lines under the question.

1. *False* Fluoride helps to make water softer.

Fluoride does not make water softer or harder.

2. *True* Some waters naturally contain fluoride.

3. *True* Properly fluoridated water helps prevent tooth decay.

4. *True* Fluoride chemicals can be added to the water by solution feeder or dry feeder.

5. *False* Fluoride chemicals must be added before chlorination takes place.

Fluoridation may take place anywhere between raw water intake and clear well storage. Recommended application is in filter effluent or clear well influent.

6. *True* Too much fluoride in the water can damage healthy teeth.

7. *False* No protective equipment or clothing is necessary when working with fluoride chemicals.

These chemicals are toxic. Rubber gloves, apron, and a toxic dust mask should be worn.

8. *True* Fluoride chemicals could cause serious damage if splashed on the skin or in the eyes.

9. *True* The fluoride content may be reduced during summer months because more water is consumed.

COMPETENCY: Determine the correct dosage of fluoride for your water treatment system.

Objective: Identify the West Virginia Public Water Supply Regulations that relate specificially to fluoridation.

Objective: Identify the specific fluoride compound(s) that is used in your water treatment plant.

Objective: Accurately calculate the correct fluoride compound dosage for your water treatment system.

RESOURCES:

(a) West Virginia Public Water Supply Regulations, Adopted by the West Virginia State Board of Health.

(b) "Fluoride Ion Determination," Resource Sheet I.

(c) "Fluoride Monitoring and Measurement," Resource Sheet II.

(d) "Fluoride Dosage" Resource Sheet III.

(e) Laboratory equipment and supply requirements for a small water treatment plant providing complete treatment *-Green Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about fluoride dosage determination.

(b) Use the W. Va. Public Water Supply Regulations to determine the optimum fluoride concentration for your water system. It will fall somewhere between 0.7 and 1.2 ppm. Remember--to determine the dosage that will give a residual of 1.0 ppm, the *natural* fluoride content of the raw water must be considered.

(c) Using any necessary references determine how much fluoride compound must be fed at which rate in order to obtain a concentration of 1.0 ppm.

EVALUATION ACTIVITY: You will be expected to determine the amount of fluorine compound and the rate of feed necessary to obtain the optimal fluoride concentration in your distribution system. You will be expected to show your calculations. You may use any references you wish.

Note: All Fluoride samples should be distilled when using any colorimetric method.

Fluoride ion Determination
(For use with the Hellige Aqua Tester)

Preparation of Reagent: (using Hellige reagents)

1. Pipette 5 ml. of zirconium oxychloride No. 611-S752 into 100 ml. volumetric flask.
2. With constant shaking, add 5 ml. of sodium alizarin monosulfonate No. 611-S753.
3. Let stand for exactly 10 minutes, then dilute to the 100 ml mark (or add 90 ml) with acid diluting solution No. 611-S754.

ALLOW THE MIXED REAGENT TO STAND ONE HOUR BEFORE USE.

Mixed reagent, if kept refrigerated and protected from light, will remain usable for 4 to 6 weeks. If refrigeration is not available, fresh reagent should be prepared each week. Approximately 40 tests can be performed with 100 ml. of mixed reagent.

Procedure:

1. Measure a 50 ml sample of water into a 50 ml glass stoppered cylinder. NOTE: The sample must be dechlorinated. Two (2) drops of 0.5% sodium arsenite are added for each 0.1 ppm of chlorine present and then mixed well. Add two (2) drops in excess.
2. Add 2.5 ml of fluoride reagent as prepared above. Mix. Let stand one hour.
3. Place sample in Hellige Nessler Tube and read sample using the Hellige Aqua Tester.

Fluoride ion Determination
(For use with the Hach DR Colorimeter)

Reagents and Equipment:

1 Hach automatic batch Fluoride still, Cat. No. 592
1 Hach DR Colorimeter, Battery Operated
1 quart of standard 1.0 ppm fluoride solution (for making up standard - this standard has a long life without deterioration and does not need to be made up perhaps but once per year)
1 quart of SPADNS reagent
1 25 ml. graduated cylinder
1 5 ml. pipette with propipette bulb

Procedure: (NOTE: Samples containing chlorine should be dechlorinated with sodium arsenite before running sample)

1. Standardize Hach DR Colorimeter using the standard 1.0 ppm fluoride solution by measuring out 25 ml. of the standard fluoride and adding 5 ml. of the SPADNS reagent. Swirl to mix.
2. Insert the Flurode (SPADNS Method) meter scale in the meter and use the 9788 color filter. Place the colorimeter bottle that contains the prepared standard Fluoride solution in the light cell. Press the light switch and adjust the light control for a meter reading of 1.00 ppm Fluoride.
3. Place the colorimeter bottle that contains the unknown sample (25 ml of sample plus the 5 ml of SPADNS reagent) in the light cell. Press the light switch and read the ppm of Fluoride directly from the dial. NOTE: Dilutions will be necessary when the fluoride content range is greater than 2.0 ppm.

*From Water Chemistry Laboratory Manual, James E. Rosencrance, Division of Sanitary Engineering, W.Va. State Dept. of Health.

TABLE OF INTERFERENCES (for fluoride determination)

CONCENTRATION OF SUBSTANCE, IN MG/L, REQUIRED TO CAUSE AN ERROR OF (+) OR (-) 0.1 MG/L at 1.0 MG/L F.

ALKALINITY	SCOTT-SANCHIS	MEGREGIAN-MALER	SPADNS
	400 (-)	325 (-)	5,000 (-)
Al^{+++}	0.25 (-)	0.2 (-)	0.1 (-)*
Cl^-	2,000 (-)	1,800 (-)	7,000 (+)
Fe^{+++}	2 (+)	5(-)	10 (-)
$(NaPO_3)_6$	1.0 (+)	1.1 (+)	1.0 (+)
PO_4^{---}	5 (+)	5 (+)	16 (+)
SO_4^{--}	300 (+)	400 (+)	200 (+)
Chlorine	Must be completely removed with arsenite		
Color & Turbidity	Must be removed or compensated for		

*Above reading is immediate. Allowed to stand for 2 hours, tolerance is 3.0 Mg/l. 4 hour tolerance is 30 Mg/l.

TEMPERATURE EFFECT

When using the SPADNS method for rapid photometric determination of fluoride in water, temperature is an important factor. The determinations may be carried out at any convenient temperature within the range of 15° to 30° C. The important consideration here is that standards and sample be at nearly identical temperature, because an error of approximately 0.01 mg. per liter of fluoride is caused by each degree difference in temperature.

This rapid photometric determination of fluoride ion concentration uses the reactions between zirconyl ions and SPADNS (Sodium 2-(Sulfophenylazo) 1,8-dihydroxynaphthalene-3,6-disulfonate-Zirconium Lake) for color formation, followed by decolorization of the lake by fluoride ions. The reaction is immediate, stable, and follows Beer's Law in the concentration range of 0.00 to 1.40 mg. of fluoride per liter. This method, used in place of the usual alizarin-zirconium colorimetric methods, will save considerable time and increase precision. It may be applied to most water samples without any pretreatment.

This SPADNS method has become quite popular in fluoride determinations in water plant laboratories because of its simplicity and saving of time. The Hach (DR) Colorimeter, battery operated, and purchased directly from the Hach Chemical Company, Ames, Iowa, is the most popular instrument in this area for this determination. NOTE: The temperature of the standard sample and the water sample must be at 20 (+ or - 1)°C. Incorrect results will result with higher or lower temperatures when using the HACH DR Colorimeter.

USEFUL DATA FOR INJECTING FLUORINE TO MUNICIPAL WATER SUPPLIES

	Comparative Fluorine Content		Comparative Solubilities@ 17°C	Amts. required to impart 1 ppm. of Fluorine to One Million Gals. of Water	
	Average Comm. Strength	Percent of Fluorine	Pounds of Chemical Soluble in 100 lbs. of water	Pounds of Chemical	Minimum Pounds of water to Dissolve Chemical
Ammonium Silicofluoride	98%	62.71%	18.6 lbs.	13.29 lbs.	72 lbs.
Sodium Fluoride	97%	43.90%	4.22 lbs.	18.99 lbs.	450 lbs.
Sodium Silicofluoride	99%	60.01%	0.65 lbs.	13.89 lbs.	2137 lbs.
Hydrofluosilicic Acid	25%	19.76%	Soluble	42.19 lbs.	none (ALREADY A SOLUTION)
Hydrofluosilicic Acid	30%	23.74%	Soluble	35.12 lbs.	none

NOTE: The slightest drop in temperature may cause portions of ammonium silicofluoride sodium silicofluoride or sodium fluoride to settle out of solution.

SOLUBILITY (to prevent precipitation of CaF_2)
AMOUNTS OF WATER FOR FLUORIDES:

Sodium Fluoride	9.3 gallons of water for each pound of fluoride
Sodium Silicofluoride	76 gallons of water

FLUORIDE MONITORING AND MEASUREMENT*

The State Board of Health requires the Environmental Health Services Laboratory, in conjunction with the Water Supply Program, Division of Sanitary Engineering, West Virginia Department of Health, to control the fluoride level in the public water supply systems. The monitoring and control involves the analysis of a water check sample each month from the water systems fluoridating. The sample is collected by local health department sanitarians, without knowledge of the date or time of collection by the water purveyor. The sample is submitted to the laboratory, recorded as being received for that particular month, and additional information bears the name of the utility, date and place of collection, and the signature of the collector. The analysis is performed by laboratory chemists either by the specific ion electrode method (this will be discussed later) or by the SPADNS Method which is a photometric procedure using a red dye. Both are Standard Methods acceptable procedures. When the analysis is completed, a report is sent to the water utility concerned, with a copy to the local county health department. The information is recorded on a permanent ledger maintained at the laboratory and the records go back to 1950, the year that fluoridation practices started in West Virginia. In addition to the above, the laboratory submits monthly reports to the Water Supply Section of the Division of Sanitary Engineering and to the Division of Dental Health. Problems such as too low reading, high readings, no readings, etc. are usually investigated and the cause determined with corrective measures taken to assure continuous fluoridation at the correct levels. The monthly report form to utilities looks like this:

WEST VIRGINIA DEPARTMENT OF HEALTH
Environmental Health Services Laboratory
151 - 11th Avenue
South Charleston, W.Va. 25303

_____ Public Water Supply.

The water sample for fluoride analysis collected on _____

at _____ shows a fluoride content of _____ Mg/l.

( ) This exceeds the maximum recommended level of 1.3 Mg/l.

( ) This is below the minimum recommended level of 0.8 Mg/l.

( ) Satisfactory.

*Exerpts from a lecture at the WVU School of Dentistry by James E. Rosencrance, Chief Chemist, Environmental Health Services Laboratory, W.Va. State Department of Health.

In addition to the monthly monitoring done by the laboratory, the daily operational records and reports of the water plant must indicate the amount of water treated during a day's operation, the type and amount of fluoride chemical fed, and the analytical results of the fluoride level in the finished water product. Any problem encountered with the fluoridation for that day is usually recorded by the more conscientious water plant operators. Water plant operators aretrained by the chemists and engineers in the Division of Sanitary Engineering in the analysis for the fluoride ion and also the proper procedures and safety practices to be used in feeding fluoride compounds. All fluoride installations, as far as equipment is concerned, must be approved by the Division of Sanitary Engineering. The initial operation of a fluoridation set-up is done by the State Health Department engineers or chemists.

DETERMINATION OF FLUORIDE IN DRINKING WATER

Fluoride in drinking water is easily and rapidly determined using the fluoride specific ion electrode. This method involves a simple one-step dilution, and completely eliminates the need for tedious distillations and complicated colorimetric methods.

The method consists of mixing the water sample and standards with equal proportions of a total ionic strength adjustment buffer (TISAB), and reading the fluoride concentration directly in parts per million on a specific ion meter or from a calibration curve drawn for a standardized pH/MV meter. Addition of TISAB to the water samples removes three problems inherent in analyzing fluoride ion activity at low levels.

(1) TISAB buffers the solution to about pH 5.0-5.5 to avoid hydroxide interference.

(2) TISAB contains CDTA (1,2-cyclohexylene diaminetetraacetic acid) which complexes aluminum, releasing fluoride as the free ion.

(3) TISAB provides a constant high ionic strength background.

The equipment required for this analytical set-up costs approximately $900 00, and our laboratory uses this procedure almost exclusively. Most water treatment plant laboratories can't afford this analytical equipment for fluoride analyses alone and must resort to another method or methods in the water plant laboratory.

Because the quantities of fluoride normally found in drinking water are small, the analytical method must be adapted to the measurement of these quantities.

Colorimetric methods are employed at water treatment plants which may be the visual Scott-Sanchis method using alizarin dye or the SPADNS photometric method which uses SPADNS, a chemical dye. (SPADNS is an abbreviation of sodium 2-(p-sulfophenylazo)-1, 8-dihydroxy-3, 6-napthalene disulfonate). This reaction is virtually instantaneous and can be performed on a sample in three or four minutes. The Scott-Sanchis visual method takes time for color development and is not as popular or as widely used by water plant operators. Both of the colorimetric methods are subject to interferences and a distillation of the water sample is recommended. Distillation is seldom necessary when the electrode method is used.

FLUORIDE DOSAGE*

The amount of chemical fed to obtain a dosage of 1.0 ppm fluoride (F^-) depends upon the fluorine content of the chemical compound used.

Illustration:

--It takes about 14 pounds of sodium silicofluoride containing 60% F for each million gallons of water to obtain the desired 1 ppm.

--It takes about 19 pounds of sodium fluoride containing 44% F to achieve 1 ppm.

--Similar adjustments have to be made for hydrofluorosilicic acid which contains 22%-30% F.

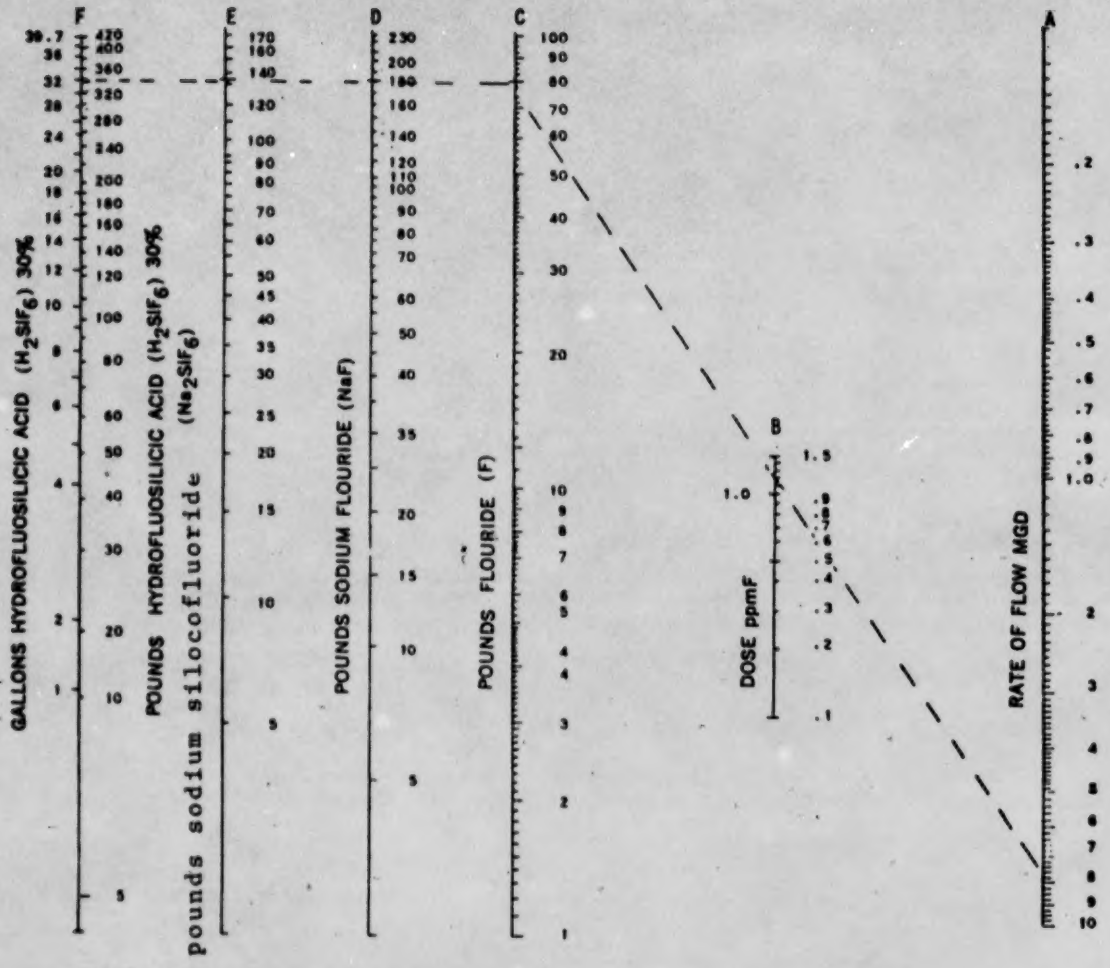
See the chart on the following page.

1. *Overall dosage checks should be made at least once a day.*
2. *Continuous observation of the equipment should be routine.*
3. *Hourly checks will reflect dosage variations and provide a basis for regulation of overfeed or underfeed.*

*Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 15, 1968, pp. 187-188.

FLUORIDATION NOMOGRAM

APPLICABLE TO ALL FLOWS AND FLUORIDE DOSAGES BY USE OF FACTORS OF 10 OR MULTIPLES THEREOF



DIRECTIONS FOR USE

TO DETERMINE HOW MUCH FLUORIDE IS REQUIRED TO INCREASE THE FLUORIDE CONTENT OF 1.P mgd- BY 1.2 ppm.

ALIGN POINT 1.P ON LINE "A" WITH THE 1.2 MARK ON LINE "B" AND EXTEND TO LINE "C" WHERE THE ANSWER IS GIVEN AS 80 LB F. BY DRAWING A LINE PERPENDICULAR TO LINE "F" AT THIS POINT, THE AMOUNTS OF THE VARIOUS FLUORIDE COMPOUNDS ARE GIVEN, i.e, 180.8 LBS NaF or 134.8 LB Na_2SiF_6 or 337.6 LB H_2SiF_6 or 31.8 GAL of 30% H_2SiF_6

Chart for Determining Dosages of Fluorine-Bearing Chemicals.

COMPETENCY: Demonstrate how to measure fluoride chemicals and properly dispose of the bags while exhibiting the use of all necessary protective equipment.

Objective: Describe the various types of feeders which may be used for applying fluoride chemicals to water.

Objective: Demonstrate how to measure the correct amount of fluoride chemical and place it in the feeder.

Objective: Demonstrate the use of proper safety precautions while working with fluoride chemicals and disposing chemical bags.

RESOURCES:

(a) Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 15, 1968, pp. 182-190. *-Blue Appendix-*

(b) Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter XXII. *-Yellow Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about proper procedures for measuring fluoride chemicals and disposing of the bags.

(b) Observe an experienced operator while s/he measures the proper amount of fluoride chemical and adds it to the feeder. Make note of the particular chemical and type of feeder being used.

Does the operator wear rubber gloves, a rubber apron, and face mask? Why are these safety precautions necessary?

Note that the fluoride chemical bag (or drum) is placed on boards or grids to permit air circulation. This prevents moisture from forming on the bottom of the container.

What methods are used to check the operation of the feeder?

(c) If the water treatment system has wells equipped with automatically controlled pumps which do not deliver to a common point, it is necessary to have an individual fluoride feeder for each well. What is the most accurate method of fluoridation for this type of installation?

EVALUATION ACTIVITIES:

(a) Complete Evaluation Form #34. It contains questions about proper procedures for measuring and and applying fluoride chemicals. You may not use references.

(b) While your evaluator observes, demonstrate the proper procedures for measuring fluoride chemicals, adding the chemicals to the water, and disposing of the chemical bags.

Operator _____

Evaluator _____

Date _____

Directions: Write the word "True" or "False" in the space provided next to each item. If you answer "False" write the correct answer on the lines under the question.

1. *True* Volumetric or gravimetric dry feeders can be used to apply fluoride chemicals to water.

2. *False* A contact period of 15-20 minutes should be allowed after fluoride chemicals are added to the water.

No contact period is necessary for fluoride.

3. *True* All fluoride chemicals are toxic (poisonous).

4. *True* Used bags which have contained fluoride compounds should be burned or buried.

5. *True* Rubber gloves, apron, and mask should be worn when working with fluoride.

6. *False* Fluoride should be added before filtration.

Some loss of fluoride occurs by absorption on floc particles. Application should occur at the filter effluent or the entrance to the clear well.

7. *False* Fluoride should not be fed into a line under pressure.

Where fluoride feeds into a line under pressure an auxiliary pump is used for handling the effluent from the solution chamber of the dry feeder.

8. *True* The feeding mechanism on a dry feeder should be completely enclosed.

Note: this is to prevent escape of toxic dust.

FLUORIDATION*

The presence of trace quantities of fluorine in the diet has been found beneficial in reducing dental caries in children and young adults. Statistical studies on the population in those areas of the United States where fluoride naturally occurs in the sources of water supply first indicated that where the chemical was present, children had very few dental cavities, and that this condition generally held throughout their life span. Subsequent studies and large scale experimentation in certain cities of the United States indicated that where fluoride dosages were applied in controlled optimal amount of about 1.0 ppm to the water supply, cavities in children were reduced from 40 to 65 percent. Currently, water is the most economical medium through which these trace quantities may be made available for assimilation into the enamel of the teeth through body processes.

Fluoride Chemicals

Fluoride compounds most commonly used in fluoridation are sodium fluoride (NaF), sodium silicofluoride (Na_2SiF_6), and hydrofluorosilicic acid (H_2SiF_6). The first two are dry, white, crystalline salts in powder form, and the last is a corrosive liquid. All are toxic chemicals and must be handled with extreme care, from the standpoint of both bodily contact and inhalation of dust if in powder form. The use of hydrofluoric acid is not permitted because of its extreme corrosiveness and difficulty of safe handling. The powder chemicals are generally packaged in 100-pound paper bags or 350 to 400 pound fiberboard drums; acids are usually obtained in 100-pound or 55-gallon rubberlined steel drums. American Water Works Association (AWWA) specifications should be used in purchasing chemicals. Equipment cost, distance from source of supply, space available for equipment, and desirability of using certain equipment to meet local conditions will affect the choice of chemicals. Store all chemicals in a dry room convenient to the feed equipment. To protect chemicals from damage, place packages including steel drums, on boards or grids to permit air circulation to prevent moisture forming on the container bottom. Hopper filling openings should be at a suitable height to avoid the use of ladders and platforms.

Equipment for Applying Fluoride Compounds

Methods of applying fluoride chemicals at Air Force installations are as follows:

a. *Filtration and Softening Plants.* Dry feeders of the volumetric or gravimetric loss-in-weight type with dissolver, delivering sodium

*Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 15, 1968, pp. 182-90.

fluoride or silico-fluoride solution by gravity to the point of application are usually provided. Volumetric feeders (Figures 1 and 2) will deliver as little as 3 to 4 ounces per hour to treat supplies of 200,000 gallons or more daily. Gravimetric feeders (Figure 3) will feed as little as one pound per hour but are generally used to treat supplies of 5 million gallons or more daily.

Volumetric Type Dry Feeders. The maximum rate of feed for this machine at any particular plant should not exceed 12 pounds per hour and the hopper should hold at least 100 pounds but not more than 200 pounds of chemical. The hopper should be equipped with an agitator to prevent arching and assure a continuous chemical feed at all times. The feeder must feed the chemical uniformly. Rate adjustment apparatus permits precise adjustment of the feeding rate. Feeding mechanism must be completely enclosed to prevent any escape of dust. It is advisable to provide as an integral part of the feeder a weighing device or a platform scale *and a loss-in-weight indicator-recorder* which will continuously indicate and record the weight of chemicals in the feeder hopper. The dissolver or solution chamber must be completely resistant to corrosion from sodium fluoride or silico-fluoride, and provided with a removable cover and a dust tight flexible connection to the feeding mechanism. The volume of the dissolver should be at least one gallon per pound of sodium fluoride fed per hour at maximum rate of feed. For sodium silico-fluoride, the volume should be at least 5 gallons per pound fed per hour. Regardless of the chemical feed rate the volume of the dissolver should exceed 10 gallons.

Gravimetric Loss-in-Weight Type Dry Feeder. This feeder differs from the volumetric in that, instead of displacing a preset volume of chemical, a definite weight of the chemical is displaced. A higher degree of accuracy is obtained, but the saving in chemicals may not offset the increased costs of a gravimetric feeder. The scales, hopper, all the mechanism, and the dissolver or solution chamber should be completely enclosed. A totalizer should show the total amount of chemical fed, in pounds, on a direct reading counter without the use of multipliers. The accuracy of the totalizer should be better than 99 percent. The hopper capacity and scale beam capacity should not exceed 250 pounds. The hopper should be filled from the floor on which the feeder is placed, or from an overhead charging chute or funnel extending to the floor above. The hopper should be fitted with suitable agitators to prevent arching. The dissolver or solution chamber should meet the same requirements as for volumetric feeders.

Pressure Feeding. Where the fluoride feeds into a line under pressure, an auxiliary pump is used for handling the effluent from the solution chamber of the dry feeder. Pumps should be all-bronze or other corrosion-resistant material. A float operated make-up water valve should be installed in the solution chamber to maintain a constant level above the outlet from the chamber to prevent air from being pumped into the system. Clogging and scaling of centrifugal or turbine type pumps used to move fluoride solutions may be expected if hard water is used for make-up purposes. To prevent

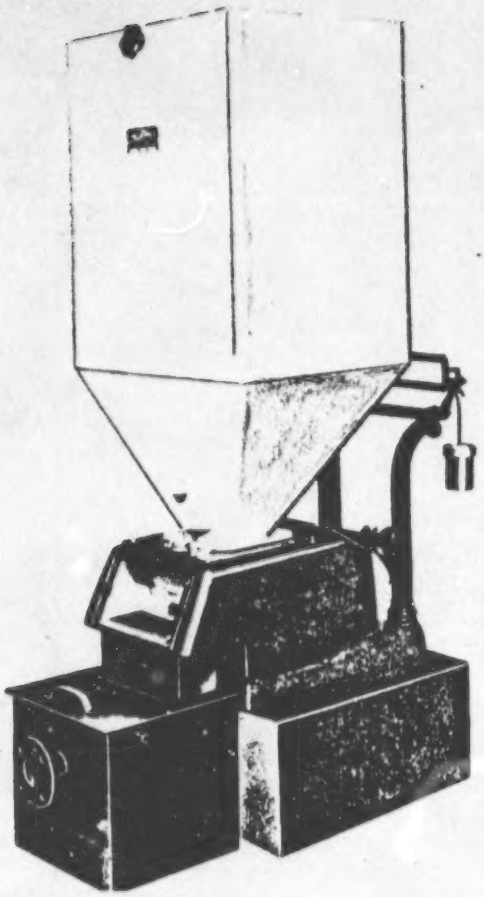


Figure 1. Volumetric fluoridizer with bag-loading hopper and dissolver.

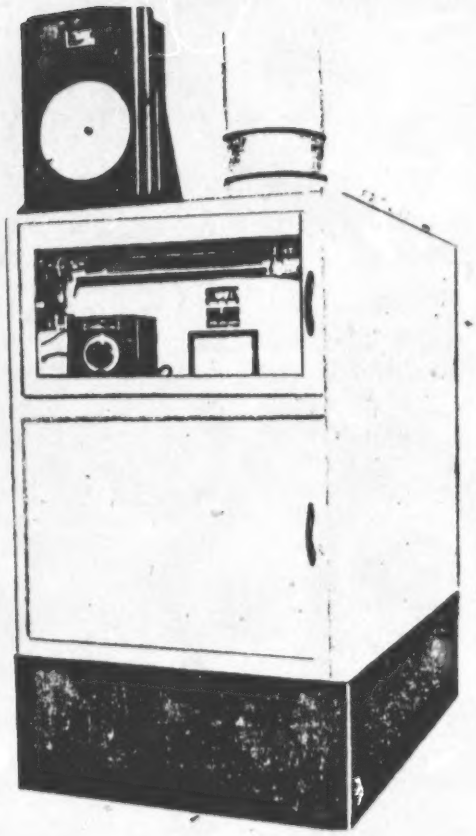


Figure 3. Gravimetric fluoridizer with recorder and chute for filling floor above.

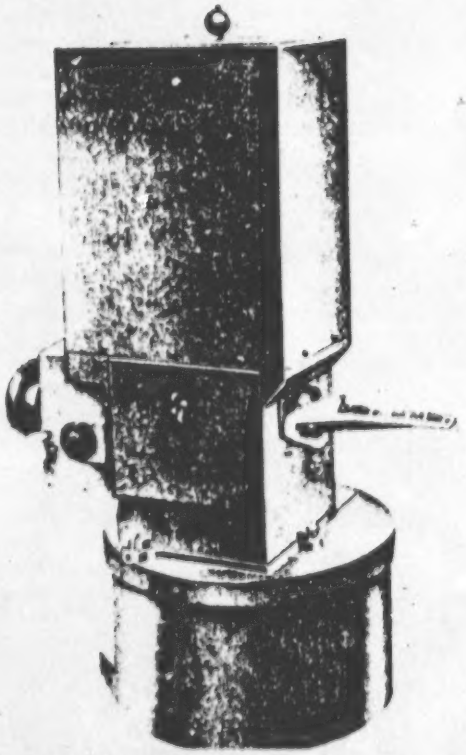


Figure 2. Type NA volumetric dry feed fluoridator.

this, soften the water or treat it with 7 to 15 ppm of Calgon, Nalco 918 or equivalent.

b. *Well Supplies.* At installations having wells that are equipped with automatically controlled pumps which do not deliver to a common point, it will be necessary to have an individual fluoride feeder for each well. For these installations the most accurate and economical method of fluoridation is by the application of *sodium fluoride* solutions of less than 4 percent. For the preparation of solutions less than saturated (4 percent), a weighed amount of the chemical is added to a definite weight or volume of water and the mixture mechanically or manually stirred until a homogeneous solution results. Often two reagent tanks are used, one tank being prepared while the other is in use. Each tank should have sufficient volumetric capacity to hold a 30-hour supply of reagent (58 gallons of 4 percent NaF solution are required for 1 ppm dose per million gallons, or 116 gallons of 2 percent solution, etc.). To reduce the hazard created by the poisonous dust of the powdered form, it is recommended that the granular form (20-40 mesh) of sodium fluoride be used in this operation. The use of "saturator tanks" for the preparation of the solutions is also recommended. For testing purposes the reagent tank should have a scale attached to the inside that can be easily read by the operator. A sight glass may be installed. Water used for making sodium fluoride solutions is zeolite softened or treated with sequestering agent such as Calgon, Micromet, Nalco 918 or equivalent where the total hardness exceeds 100 parts per million expressed as calcium carbonate. Solution feeders commonly used are positive displacement diaphragm pumps with feeding heads constructed of polyvinyl or methyl methacrylate plastic and neoprene, which are resistant to fluoride chemicals. Installations of the constant rate type will require automatic start-stop mechanisms to permit the equipment to function only while the well pumps are in operation. Provide a relay in the starting circuit to a deep well pump motor to start and stop the chemical feeder motor. For dry feeders, a solenoid valve which opens when energized should be installed in the water line to the solution chamber. In installations where the flow varies hourly or is changed several times a day, automatic proportioning is required, wherein the feeder rate is automatically adjusted in proportion to the flow as indicated by a meter. Either venturi or propeller type meters may be used. Accuracy of this proportioning can be determined and recorded by checking the volume pumped with the weight of fluoride used. Automatic proportioning will be provided on all well pumps that start and stop automatically and do not deliver to a common point. Figures 4 through 7 show typical fluoride installations.

Wells Pumping to Central Point Before Distribution. Where the source of water is from wells pumping to a central point, such as a reservoir or ground storage tank, and then pumped into the distribution system, fluorides are applied by any of the methods shown in Figures 4 through 7, whichever is more feasible.

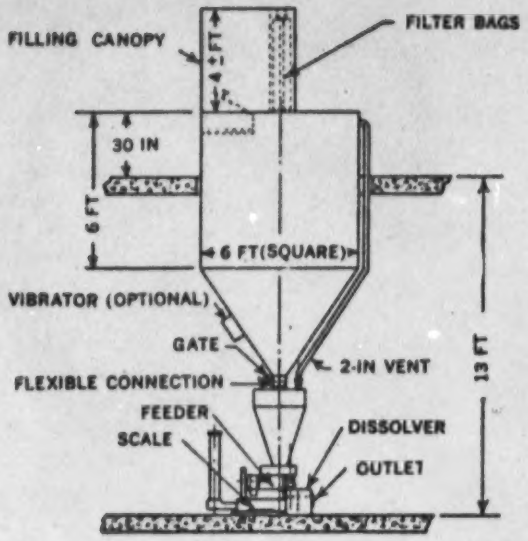


Figure 4. Chemical feeder and storage hopper.

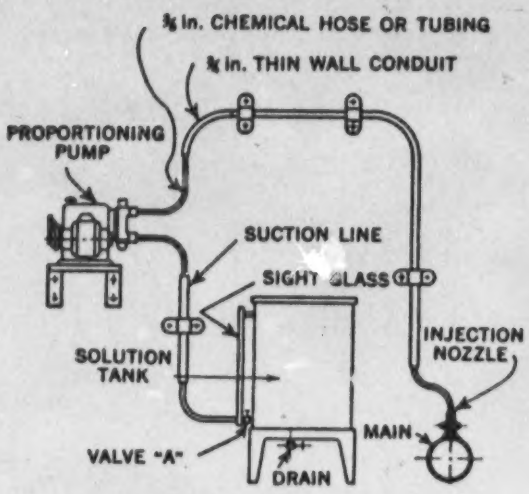


Figure 5. Proportioning pump installation---injection into pipeline.

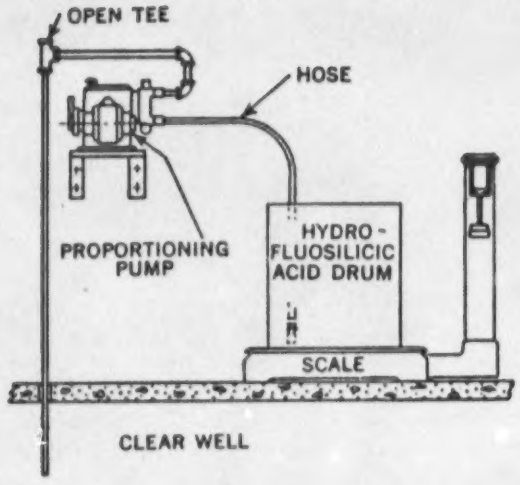


Figure 6. Proportioning pump installation---application to clear well.

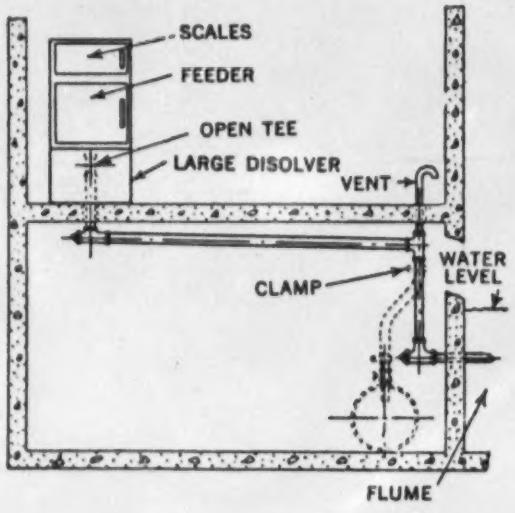


Figure 7. Gravity feed installation.

Points of Application

In feeding fluorides it is not necessary to allow for a contact period as with chlorination. Because some loss of fluoride occurs by adsorption on floc particles either in flocculation or softening processes, the most desirable point of application is in the filter effluent or at the entrance to the clear well. At installations using well water the solution is normally injected into the discharge from the well pumps unless water is discharged to a central point for storage. Fluoride chemicals are added after all other chemicals have had an opportunity to react, but prior to final chlorination. Water has no "fluorine demand", hence the entire quantity can be accounted for in the distribution system unless it is lost through the treatment process. Ordinary filtration occasions a loss of 0.1 to 0.3 ppm of the fluoride added; about 25 percent of the fluoride ion is lost by feeding fluoride solution ahead of the lime-softening process. Generally, fluorides are applied most effectively where the risk of losing them in subsequent treatment is least.

Dosage

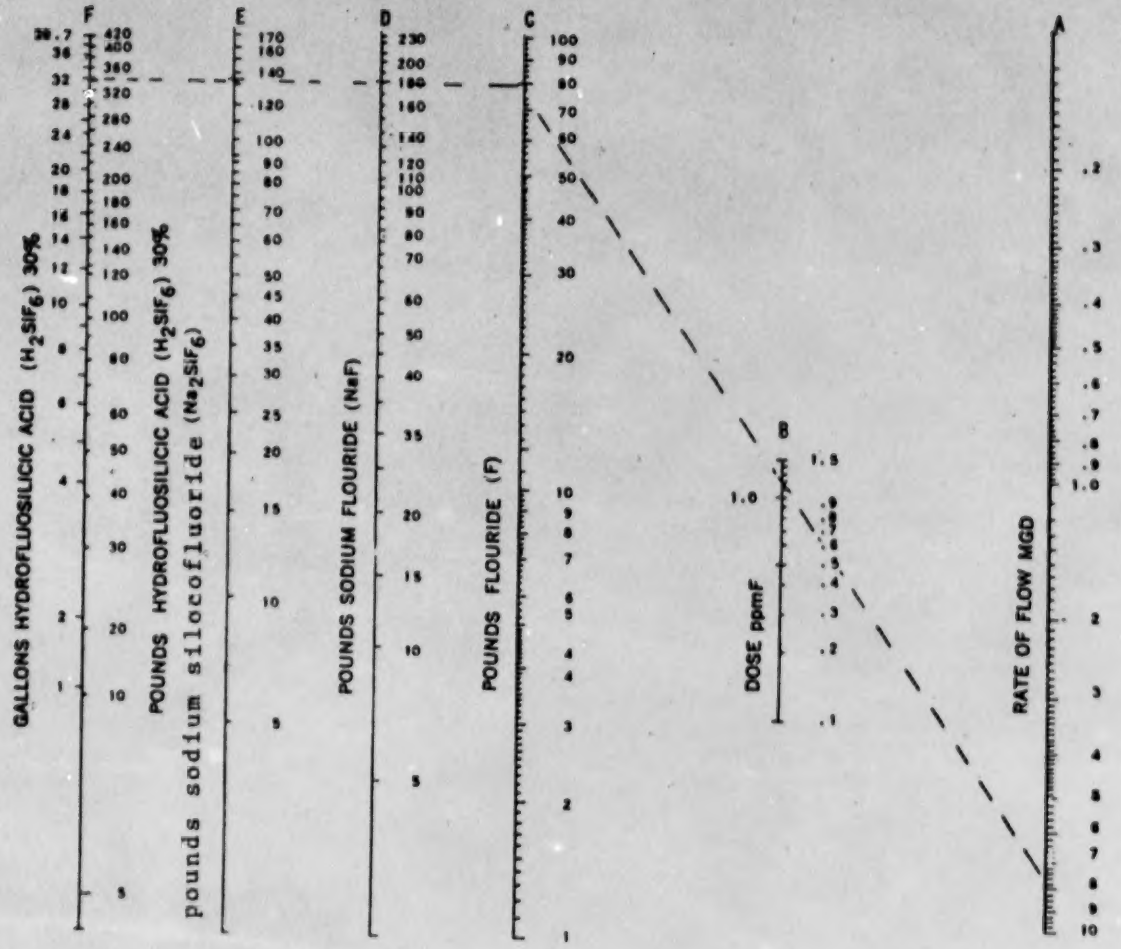
In fluoridation practice the target residual in the distribution system is prescribed for each installation by the Surgeon General. Due to the greater average intake of water in warm climates, the prescribed fluoride residual is lower than in cold climates. In general, the spread is from 0.7 to 1.2 ppm of fluoride in the finished water supply, the average being about 1.0 ppm. To determine the dosage that will give a residual of 1.0 ppm, the natural fluoride content of the raw water must be considered. However, this content is generally so small (usually 0.10 to 0.25 ppm) in those areas where fluoridation is practiced that little adjustment has to be made in the amount of the dosage if application is made after coagulation and sedimentation, which tend to remove part of the natural fluoride. The amount of chemical fed to obtain a dosage of 1.0 ppm of fluorine (F^-) depends on the fluoride content of the chemical compound used. As an illustration, it takes about 14 pounds of sodium silicofluoride containing 60 percent F for each million gallons of water to obtain the desired 1 ppm, while approximately 19 pounds of sodium fluoride containing 44 percent F are needed to achieve the same results. Similar adjustments have to be made for hydrofluorosilicic acid, which contains 22 to 30 percent F. Figure 8 illustrates the method of determining the desired dosages for various fluorine-bearing chemicals. Chemical dosages must be set and supervised by properly authorized personnel. Overall dosage checks are made at least daily. Continuous observation of the equipment is a daily routine operation. Hourly checks reflect any dosage variations and provide a basis for regulation of overfeed or underfeed.

Sampling and Analysis for Fluoride

a. *Sampling.* Representative composite samples from the treatment

FLUORIDATION NOMOGRAM

APPLICABLE TO ALL FLOWS AND FLUORIDE DOSAGES BY USE OF FACTORS OF 10 OR MULTIPLES THEREOF



DIRECTIONS FOR USE

TO DETERMINE HOW MUCH FLUORIDE IS REQUIRED TO INCREASE THE FLUORIDE CONTENT OF 1.P mgd- BY 1.2 ppm.

ALIGN POINT 1.P ON LINE "A" WITH THE 1.2 MARK ON LINE "B" AND EXTEND TO LINE "C" WHERE THE ANSWER IS GIVEN AS 80 LB F. BY DRAWING A LINE PERPENDICULAR TO LINE "F" AT THIS POINT, THE AMOUNTS OF THE VARIOUS FLUORIDE COMPOUNDS ARE GIVEN, i.e, 180.8 LBS NaF or 134.8 LB Na_2SiF_6 or 337.6 LB H_2SiF_6 or 31.8 GAL of 30% H_2SiF_6

Figure 8. Chart for determining dosages of fluorine-bearing chemicals.

plant effluent should be collected and analyzed daily in addition to the dosage checks for plant control. If laboratory control is not available at a plant, samples should be shipped to a designated laboratory for analysis. No precautions other than that chemically clean sample bottles shall be used. Sampling from representative points in the distribution system should be performed at least weekly and preferably twice a week as a further means of evaluating the effectiveness of plant control.

b. *Analysis.* For plant control, analysis may be by colorimetric methods, the principle of which is employed in commercially produced comparators similar to those shown in Figures 9 and 10. These comparators do not require technical skill to operate and are a satisfactory method of checking plant control and distribution residuals. Directions for eliminating or reducing interfering substances are furnished with the testing equipment. Pre-distillation of the sample is recommended for all colorimetric determinations to minimize interferences.

Safety

Fluoride dusts may cause irritation of the skin and mucous membrane. Personnel working with these chemicals must be trained in their safe handling. Wear rubberized gloves, plastic or rubber aprons, and masks when exposed to the dust. Dust must be removed immediately from the skin by bathing or washing. Remove spilled fluorides by wet mopping. Detailed instructions on handling and safety precautions to be taken will be posted at the point of operation and adequately enforced. All fluoride packages must be labeled with a sign warning that a poison is contained therein. Used paper sacks may be disposed of by incineration or burying in the sanitary fill. To insure safe disposal, this operation will be supervised by personnel familiar with the hazards involved. There will be no cross connections between solution tanks and the potable water supply. If cross-connected, a lowered pressure in the water distribution system could permit the concentrated fluoride solution to siphon back into the water system, thus endangering the health of water consumers. In fluoride solution tanks the water supply line must terminate above the highest chemical solution level and provide an air break.

Corrosiveness of Fluorine-Bearing Chemicals

Most solutions of fluorine-bearing chemicals are of low pH (2.5 to 4.5) and are highly corrosive. They must therefore be handled in corrosion-resistant containers or tanks. Rubber-lined or plastic-lined steels tanks and rubber-lined or plastic piping are necessary for the retention and conveyance of these chemicals. The dry powder form of fluorides such as sodium silicofluoride and sodium fluoride does not readily take up moisture from the air and therefore is less corrosive by direct contact with metals than a solution containing it. However, dry feed machines must be designed especially to handle the material. Prevention of corrosion in these systems must generally be handled in the engineering and design of the system. Periodic inspection of tank linings and piping is very important and should be made a part of routine preventive maintenance.

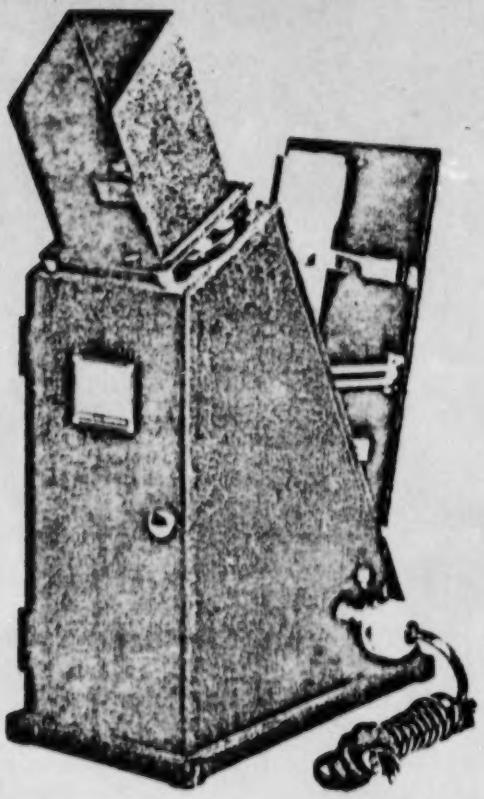
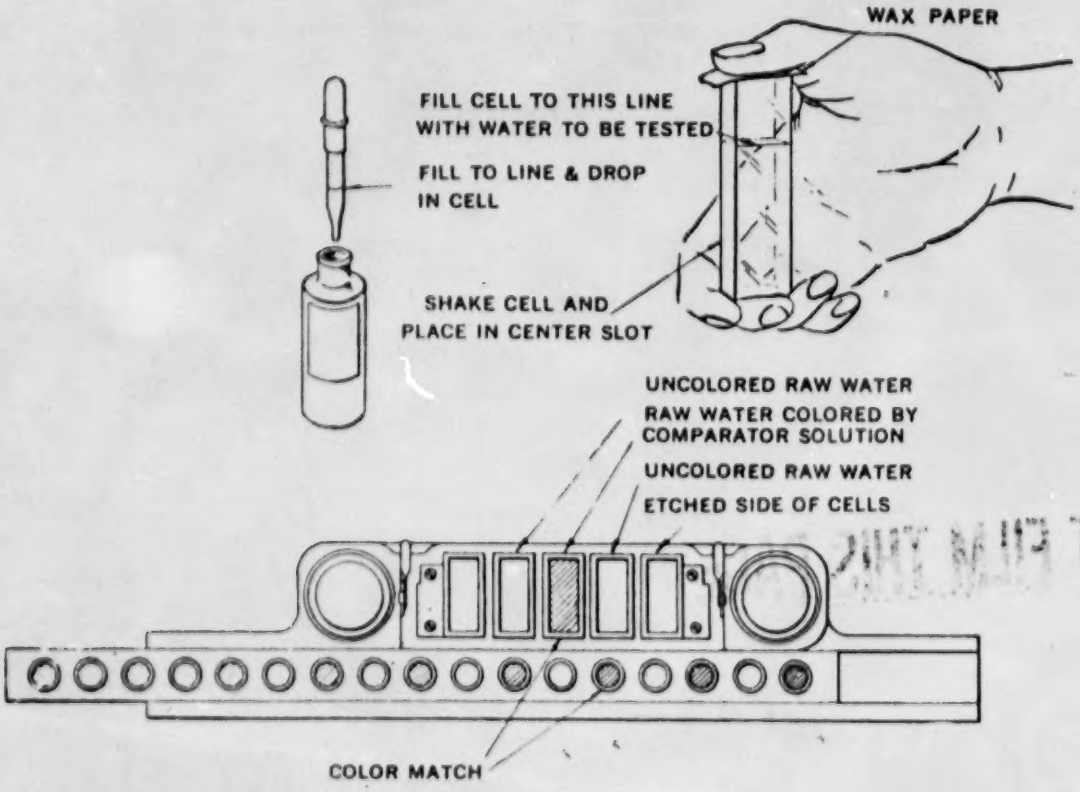


Figure 9. Disc comparator for determining fluorine residual.

Figure 10. Slide comparator for determining fluorine residual.



FLUORIDATION OF PUBLIC WATER SUPPLIES*

Fluoridation is the adjustment of the fluoride content of a public water supply up to the level required for the prevention of dental decay. Fluoridation does not affect the taste, odor, or color of water. It neither adds hardness to the water nor affects the use of water for any domestic or industrial purpose.

Fluoride occurs naturally in many ground and surface waters and foods. Some water supplies contain no fluoride, others less than the desired amount, some too much, and others just the right amount.

The optimum or desired level is defined as that most favorable or that conducive to a given end, and there is an optimum level for the fluoride content. In general, the optimum fluoride content is considered to be approximately one part per million. For ages people have believed that mineral drinking waters are beneficial, but it has been only a couple of generations now that public health people have known the great benefit a population can obtain by drinking water with an optimum fluoride content. This chemical, fluoride, of course, is not the gas, fluorine, but is in the form of a salt, such as sodium silicofluoride, in solution. This would be similar to comparing chloride to chlorine.

In 1908, a young dentist named Frederick McKay, of Colorado Springs, Colorado, became concerned about the great amount of tooth discoloration among children in his community. This discoloration, which Dr. McKay and an associate, Dr. G. V. Black, called "mottled enamel" was also found among children of all the surrounding communities; that is, all except one. That one community did not obtain its water supply from the Pikes Peak watershed. Dr. McKay believed the mottling to be related to something in the water supply. This "something" was not discovered, however, until 1931 when H. V. Churchill, an industrial chemist, showed that water from Bauxite, Arkansas, contained 14 parts per million fluoride and, thereby, led to the association of excessive amounts of fluorides in water supply and mottled enamel. Further studies showed that severity of mottling increased with increasing fluoride content and vice versa, with no apparent mottling when the water supply contained less than 1.5 parts per million fluorides.

As a result of this information, communities with excessive fluorides in their water supply began changing to a fluoride-free water. Subsequently it was observed that, in communities which had changed to a fluoride-free water supply, the incidence of decayed teeth among children began to increase. This observation, when related to the knowledge that, in areas where mottling was prevalent there was less tooth decay, led to studies to find if there was a fluoride concentration which would provide control for tooth decay but cause

*Source: Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter XXII.

no enamel mottling--in other words, an optimum fluoride content. Dr. H. T. Dean and others showed that water supplies with one part per million fluoride would provide a maximum of dental caries prevention and still not cause the objectionable mottling of teeth.

It should be pointed out that these conclusions resulted not only from work done in the United States, but also in England, Switzerland, Sweden, Italy, India, South Africa, Japan, and South America. It should also be pointed out that these studies were made on waters with a natural fluoride content. Therefore, the next logical step was to determine if a water supply with fluoride added would provide the same protection against tooth decay. In order to find out if the addition of fluoride to water supplies that were deficient in fluoride would give the same benefit as water naturally containing an optimum amount of fluoride, a series of control studies were started in Grand Rapids, Michigan; Newburgh, New York; and Brandtford, Ontario, in 1945 and in other communities at later dates. By 1950, results of these studies were proving so favorable that many felt it unnecessary to wait longer and began implementing fluoridation programs in their own communities.

After twenty years of experience, the answer is still decidedly "yes" that the addition of fluoride to provide an optimum level in the water supplies will reduce tooth decay among children by approximately two-thirds. This control of decay results in the loss of fewer teeth, and the benefits obtained in childhood carry over into adulthood. So it is not only the children who benefit, but all people who drink fluoridated water from birth through childhood. In 1967, there was considerable evidence that there may be other benefits with regard to bone structure; and this is being investigated.

Notwithstanding the many loose claims that fluorides damage the health of consumers, extensive studies show that the drinking of water containing one part per million or less of fluoride will not harm the body in any way. Is it any wonder, then, that so many communities, finding their water supplies deficient in fluoride, are increasing the fluoride content to the optimum level?

As of December 31, 1967, the number of communities in the United States with fluoridated water supplies had grown to approximately 4,000, serving a population of nearly 82 million. Add to this the more than 10 million on naturally fluoridated water supplies and the total population on fluoridated water comes to 92 million persons or approximately 46 percent of the total population.

Addition of Fluoride

Any community whose public water supply does not contain enough fluoride to prevent decay can adjust the fluoride content of the water. This is a relatively inexpensive process and consists of adding the proper amount of the source chemical by means of a suitable chemical feeder. Water works operators, who are already

adding chemicals, such as lime or chlorine, to the water, will find the addition of fluoride very similar.

Amount Required

The amount of material that must be fed depends upon the amount desired in the finished water, the amount already naturally present in the water, and the fluoride source selected. The optimum concentration of fluoride ions (F^-) in the finished water is generally designated by the State Board of Health as 1.0 part per million in the winter and 0.7 part per million in the summer months. More water is consumed in summer; therefore, the fluoride content can be reduced during this season. Where fluoridation is to be practiced, enough fluoride-containing chemical must be added to the water to bring the fluoride content up to 0.7 to 1.0 part per million.

If the water supply contains no natural fluoride and sodium silicofluoride is used, then 14 pounds of this material must be added to each million gallons of water in order to have 1.0 part per million (ppm). If hydrofluosilicic acid is used, then approximately 46 pounds, or 4.5 gallons, are required to provide 1.0 ppm fluoride in a million gallons of water. The exact amount of either chemical required will vary according to the per cent purity of the commercial product used.

It can be seen from this that, in producing only 100,000 gallons of water per day, the amount of chemical to be fed will be very small and the type of feeding machine will be quite different from one required to add several hundred pounds per day to millions of gallons of water.

Fluoride Chemicals

For source chemicals, two compounds commonly used are--sodium silicofluoride (Na_2SiF_6) and hydrofluosilicic acid (H_2SiF_6). In the earlier years acid was considered too much of a safety hazard, from the operators standpoint, and it was the higher priced substance. However, experience indicates the hydrofluosilicic acid is less hazardous than the powdered sodium silicofluoride. There have been cases where hydrofluosilicic acid was splashed in eyes and serious injury was avoided by immediately washing with water. Hydrofluosilicic acid (H_2SiF_6) should not be confused with hydrofluoric acid (HF) which is very dangerous and corrosive and must not be used. Hydrofluoric acid is the acid used to etch glass.

Sodium silicofluoride is available as a powder of approximately 98 per cent purity containing 60 per cent fluoride. The chemical will cost about $0.0975 per pound, making the fluoride cost about $0.16 per pound. Sodium silicofluoride is only sparingly soluble, 0.75 per cent at 75°F., (less than one per cent) and, therefore, is fed practicably only by the dry feed machine. A slurry feed has been suggested but is not recommended. When fed by a dry feed machine,

sodium silicofluoride is considered to have a practicable solubility of about 0.2 per cent. Water must be added to the solution pot in sufficient amounts to dissolve all the chemical fed. Approximately 60 gallons per pound of chemical is required. The solution pot size should be sufficient to provide a detention period of about 5 minutes. Because this solution is quite corrosive, the solution pot should be made of stainless steel or some other corrosion-resistant material. The piping is usually plastic or rubber.

Hydrofluosilicic acid is usually available in 23 per cent strength and contains approximately 18 per cent fluoride. The price varies considerably according to the source and the quantities ordered. Fairly recent figures show the cost varied from $0.0335 per pound delivered in 3,000-gallon lots to $0.08 per pound delivered in 15-gallon drums. This would make the cost of available fluoride vary from $0.185 to approximately $0.45 per pound. However, in many cases it has proven competitive with sodium silicofluoride when manhours, convenience of storage, handling, and simplicity of feed of the full strength acid is considered. This acid is fed by a displacement pump, or chemical metering pump (hypochlorinator), either with or without dilution of the acid. In some areas difficulty has been encountered in diluting the acid. In plants having a capacity less than 800 gpm, the fluoride is fed intermittently by controlling the feeder by means of a timer. However, the acid is diluted when the well capacity is less than 800 gpm.

Facilities to store large quantities of either chemical would be about equal. If full advantage is to be taken of tank truck load prices for acid, then storage must be available for a load or smaller users must split loads. It is hoped that in the future it will be practical and profitable for the supplier to provide acid by tank truck to all users. The small water works might store acid in lined 55-gallon drums and benefit from a price advantage.

Fluoride Feeders

Devices for feeding fluorides accurately have generally been adapted from those machines originally designed for feeding a variety of chemicals in water treatment and industrial plants. Feeders can be broadly divided into two types: (1) solution feeders, where a measured volume of either an accurately prepared fluoride solution or of the hydrofluosilicic acid is delivered during a specified period; and (2) dry feeders, where a predetermined quantity of the solid material is fed during a given time interval. The choice of a feeder depends on the rate at which fluoride is required. This rate is in turn determined by the rate of water production and the fluoride content of the untreated water. Solution feeders are generally used for smaller supplies and, of course, in all plants using the hydrofluosilicic acid. The dry feeders are used in the larger plants utilizing sodium silicofluoride. There is, of course, a wide area within which either type would be equally successful.

It is doubtful that dry feeders will be used to any extent in the

future. Dry feeders are of two general types: (1) volumetric feeders, which deliver a measured volume of dry chemical within a given time interval; and (2) gravimetric or loss-in-weight feeders, which deliver a measured weight of chemical within a given period.

There are continuously operated diaphragm solution feeders (hypochlorinators) with minimum delivery rates varying from 2.5 to 12.6 ml. per minute. By intermittently operating the feeders with timed relays, deliveries can be reduced considerable. The solution feeders of the displacement pump variety can feed the solution against pressure into a pipe or tank of water under pressure, as well as into open tanks of water. The dry feeder must have a pump or ejector if the solution is to be introduced into a pressure system. Solution feeders are considerably less expensive than dry feeders. A solution feed installation might be had for $400 to $600, whereas a dry feed installation will cost from $1,300 to $3,300, according to whether a volumetric or a gravimetric feeder is used (the latter being more expensive and usually more accurate).

Point of Application

In addition to selecting a source chemical and a feeder to apply it, it is also necessary to decide where it should be applied. Fluorides may be applied to the water at any point between the raw water intake to the clearwell storing the treated water. The point of application will be selected based on conditions at each separate water supply.

In many cases, well supplies require no treatment other than chlorination and are pumped directly into the system. In a system such as this, fluoride must be fed at each well. The installation must be so arranged that the feeders operate when the pump is running and the application may be made without fear of reactions with chlorine as there are no known reactions between fluorides at 1.0 ppm in water and compounds formed in water after chlorination. The main precaution required in feeding fluoride into a well supply is to provide sufficient mixing to be sure the water will have a consistent optimum fluoride content prior to reaching the first consumer outlet.

Personnel Protection

Because these chemicals are toxic, certain handling precautions must be taken. When only small amounts of chemicals are handled, protection of the operator is fairly simple. Rubber gloves and toxic-type dust mask will protect the operator when handling fluoride chemicals. If only small amounts of chemical are transferred each day from a drum to a feeder hopper or to a tank in which solution is being mixed, the likelihood of toxic dusts being spread throughout the room is much less than when drums or sacks are being emptied into large hoppers. In handling dry, dusty fluoride, provisions must be made to protect the operator

and will require a satisfactory dust collector. Spilled chemicals should not be swept but should be wet mopped. Sweeping dry chemical creates excessive dusts.

An emergency shower with easily operated controls, or certainly a spigot, should be located in the area where acid is handled. Immediate flushing of the eyes or other portions of the body should follow splashes or spills. If acid should splash in the eyes, to delay flushing may result in serious damage. Regardless of which chemical is used, it is necessary that every precaution be taken to protect the operators from the toxic effects of the concentrated fluoride chemicals.

Operation Control

Controlling the dose of fluoride or the fluoride level in the water supply is the most important part of the fluoride treatment process. If the fluoride level is not kept up to optimum, consumers will lose the full benefit; or if it is kept too high, some consumers might experience some mild mottling of the teeth. Fluoride feeding might be compared somewhat to the feeding of polyphosphate, where feeding an insufficient amount does not prevent corrosion or scaling and feeding too much results in money lost in the form of excess chemical waste. Benefits are obtained in a similar way also. If corrosion is prevented, the equipment and distribution system will last longer and upkeep costs will be less. When the optimum amount of fluoride is provided and thereby dental decay is prevented among the children, their teeth last longer and dental costs are reduced. Of course, the real benefits of either of these treatments are not seen in a week, a month, or even a year. Because results cannot be observed in a short period, accuracy and continuity of control are important.

In order to maintain proper fluoride dosage, adequate records must be kept of how much chemical is fed each day, how much water is treated each day, and results of the analytical determinations (tests) for fluoride. If the calculated dosage and fluoride content do not agree with the analytical results, it is necessary to find out why and make the necessary adjustments. If the discrepencies cannot be explained and corrected, call for help from the State Health Department.

When a community decides that it should fluoridate, it is up to water works people to treat it in as efficient a manner as possible. If additional equipment is needed, or help to provide for proper fluoridation of the supply, let the officials know what is needed. In some supplies, there are no master meters. It is not very satisfactory to have to depend upon calculating the amount of water treated by using pump capacity and time of pump operation, particularly when the maintenance of proper fluoride concentrations is concerned. Facilities must be such that there is some method for satisfactorily determining the amount of fluoride in the water. Prior to fluoridation, the operator may or may not have been required to run chemical tests other than chlorine residual; but

after beginning fluoridation, tests are required daily. These are time-consuming, requiring more than an hour.

Some have said anyone who can run a chlorine residual test can run a fluoride test. This may be true; but notwithstanding the apparent simplicity of the test procedure, fluoride determination is by no means foolproof. The operator must know the limitations of the test and the precautions required to obtain reasonably reliable analytical results. There are several acceptable procedures for determining the fluoride content of water. STANDARD METHODS describes three methods and also a distillation procedure which will eliminate possible interfering substances prior to testing.

A common interference is free residual chlorine, it must be removed. Chlorine will react with the fluoride reagent in such a way as to cause errors. It is, therefore, necessary to eliminate the chlorine in a sample before adding the fluoride reagent. This is effectively done by adding 2 drops of a 0.1 N sodium arsenite ($NaAsO_2$) solution to the 100 ml. sample. Other substances which will cause interference include: hexametaphosphate, phosphate, aluminum, iron, high sulfates, alkalinity or chlorides.

Many state health departments require periodic submission of samples for check analyses. Records of these checks are beneficial to both the water facility and the State Health Department. The results of these tests are sent to the water supply's responsible official. The results should be compared to the plant record to compare results. Not only does this provide a check on the fluoridation procedure, but it gives the operator a chance to check his procedure and test results.

It can be seen that fluoridation requires an operator with certain qualifications. If he doesn't have these qualifications, and the community wants fluoridation, he must gain the necessary knowledge and laboratory skill required. For this reason, the State Board of Health's Policy and Standards are considered as having been complied with when the operator holds a Certificate of Competency or is a certified operator.

Regardless of the kind of fluoridation installation planned for a community, the approval of the State Board of Health must be obtained before operation is started. Therefore, consult them before doing any planning on a fluoridation operation.

Partial Defluoridation of Water

The fact that approximately 1.0 ppm of fluorides in water will prevent dental decay and that excessive amounts of fluorides (over 1.5 ppm) will cause "mottled enamel" have been discussed along with how water supplies that are deficient in fluoride can correct this problem. However, what can a community do if they find their water supply contains more than the optimum amount of fluoride? There are three alternatives: (1) Locate a new source of water with a lower fluoride concentration; (2) remove part of the excess

chemical by defluoridation; or (3) utilize the water available, which may result in discoloration of teeth, the severity depending upon the concentration above 1.5 ppm.

Defluoridation is accomplished by a special ion-exchange type system. Activated alumina is used at the plants in Bartlett, Texas, and Camp Irwin, California. The only other plant in operation in the United States is at Britton, South Dakota; it utilizes bone char as the media. In these two processes, the water is passed through the media (in either gravity or pressure tanks). After the media is saturated with the fluoride that was removed from the water, it must be regenerated by chemical treatment.

Another defluoridation method has been developed, but at present no plant has been constructed to use this process. In this method magnesium is added to the water in the form of dolomitic lime. The dolomitic lime, after absorbing the fluorides, is removed by passing the water through settling basins and filters and is then discarded.

Health Department Policy and Standards

Fluoridation is many times a highly controversial subject. When consideration is given to adjusting the fluoride content in a public water supply, arguments range from accusation of mass medication to invasion of Constitutional rights. Certain religious sects and other groups are strongly opposed to artificial fluoridation. Since it is controversial and must be properly applied to derive the desired results, the State Board of Health has adopted certain rules and regulations. As indicated previously, an insufficient amount added to the water will not satisfactorily reduce the incidence of dental decay. Too much fluoride can produce mottled enamel (discoloration) and is unnecessarily expensive. Thus, by properly controlling the fluoridation application, desired beneficial results are obtained at the least possible cost.

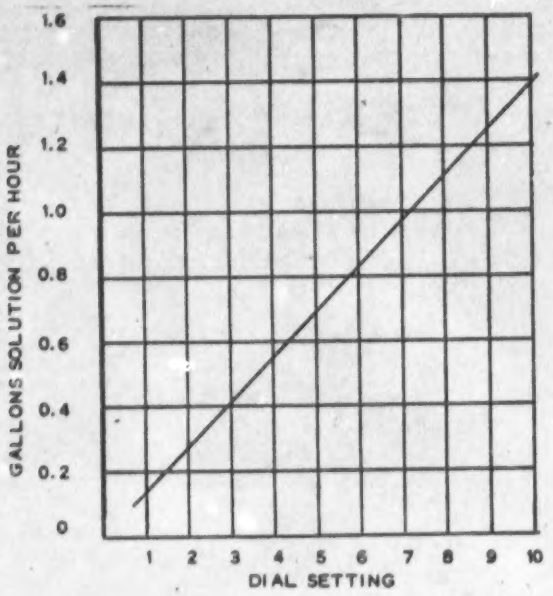
EXAMPLE

As mentioned in the appendix, when a solution feeder, adjusted to its lowest setting, will deliver more fluoride than needed, a timer must be installed. This permits adjustment so that the feeder will operate only a portion of the time. Below is an example relative to such an installation.

One gallon of 23% hydrofluosilicic acid contains 18% available fluoride by weight, and 1 gallon of 23% hydrofluosilicic acid weighs 10.3 pounds.

A treatment plant produces 1 MGD (700 gpm) and 0.2 ppm fluoride exists naturally in the raw water. It is during the summer season that 0.7 ppm fluoride in the finished water is required.

A graph showing the amount of solution a Wallace & Tiernan A-747 feeder will deliver at the various dial settings, with pulley set at 4 strokes per minute, follows:



The questions are:

1. How much acid must be fed per hour?
2. With a dial setting of 2, what percent of time would the feeder operate? (Use the graph.)

ANSWERS

Question 1. How much acid must be fed?

0.7 ppm (desired) minus 0.2 ppm (natural) equals 0.5 ppm to be added.

$$ppm = \frac{\text{pounds} \times 120{,}000}{\text{gallons treated}}$$

Note: the 120,000 results from dividing 1,000,000 gal. by 8.34 lbs./gal. of water.

$$0.5 = \frac{\text{pounds} \times 120{,}000}{700 \text{ gpm} \times 60 \text{ min.}} = \frac{\text{pounds} \times 120{,}000}{42{,}000}$$

$$\text{Pounds} = \frac{.5 \times 42{,}000}{120{,}000} = 0.175 \text{ pounds of fluoride per hour to be added.}$$

10.3 (pounds/gallon) x .18 (per cent fluoride) = 1.854 pounds of fluoride per gallon of acid.

Thus, $\frac{0.175 \text{ pounds needed}}{1.854 \text{ pounds per gal.}}$ = 0.094 gallon per hour needed to give 0.175 pounds of fluoride.

The feeder cannot be adjusted to reliably feed this small quantity, and the timer is needed.

Question 2. What per cent of time would the feeder operate?

With a dial setting of 2, the feeder will pump 0.28 gallon per hour (see graph). However, only 0.094 gallon is needed.

Therefore, $\frac{0.094}{0.28} \times 100 = 33\%$ of time required for feeder to deliver the desired amount.

The timer would, therefore, permit the feeder to run only 80 strokes per hour, as compared to 240 strokes normally operating. Such an installation could, therefore, be used only at a plant with mixer, flocculator, or clearwell.

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

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Environmental Health Services
Drinking Water Program
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The following laboratory equipment and supplies are required of small water treatment plants for determining the physical-chemical parameters of chlorine residual (free and total), turbidity, pH, alkalinity, free carbon dioxide, hardness, fluoride ion, and performing the "jar test" for proper coagulant dosage.

Vendors not noted below, but capable of supplying equipment equal to that which is listed are acceptable. However, the Environmental Health Services Laboratory (telephone 348-0197) should be consulted before purchasing agreements are made with these vendors to confirm that equivalent equipment is being offered.

Item Number	Quantity	Items
1	1	Copy of latest edition of "Standard Methods for the Examination of Water and Waste Water", American Public Health Association, Inc., 1015 Eighteenth Street, N.W., Washington, D. C. 20036
2	1	Balance, Harvard Trip Scale, single beam, Ohaus #1450
3	1 set	Technical weights, metric, class C, 1 gm to 1000 gms
4	1	pH meter - accuracy ± 0.05 unit, scale readability ± 0.1 pH unit. Instruments meeting specifications of the Corning model 7, the Orion model 601, Beckman Zeromatic, Fisher Accumet, or equivalent are satisfactory. Laboratories purchasing a new pH meter are strongly advised to purchase one capable of functioning with specific ion electrodes.
5	3	Burettes, Automatic, with stopcock, for dispensing sulfuric acid and hardness reagent, also N/44 sodium hydroxide, 50 ml. capacity, 1/10 ml. subdivisions, complete with rubber bulb and reservoir.

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Item Number	Quantity	Items
6	1	Burette Support, with large white porcelain base and a 3 way castaloy burette holder for assembling and steadying automatic burettes with reagent reservoirs.
7	1	Therometer, - 10° to 110° C.
8	4	Casseroles, porcelain (Coors #180), 210 ml.
9	6	Stirring rods, glass, 3mm diameter
10	6	Pipettes, water analysis, 10 ml. capacity
11	2	Cylinders, graduate, 100 ml. capacity, 1.0 ml. subdivisions
12	3	Flasks, Erlenmeyer, wide mouth, 250 ml.
13	6	Beakers, Griffin, "Pyrex", 1000 ml. (for jar test)
14	6	Bottles, dropping T. K., 60 ml.
15	1	DPD Chlorine residual colorimetric test kit. LaMotte, Hach, Taylor or equivalent are satisfactory kits. Kits must include free and total residual capabilities.
16	1	Turbidimeter (Nephelometric only) - Hach Turbidimeter 2100 A, Sargent-Welch, Turner Designs, Monitek, or equivalent. TURBIDITY ANALYSIS IS REQUIRED ONLY FOR THOSE SUPPLIES TREATING SURFACE SOURCE WATERS. Calibration of sealed liquid turbidity standards - sealed liquid turbidity standards purchased from the instrument manufacturer must be checked frequently for settled and floating particles in order to monitor their eventual detericration. These standards should be replaced when any major change from the previous calibration occurs or sediment appears. Solid turbidity standards composed of plastic, glass, or other materials are not reliable and should not be used.

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Item Number	Quantity	Items
17	1	Distilling apparatus, automatic, bantam still, capacity 1.8 liters per hr., Barnstead or equivalent with 2 gallons of distilled water storage. (Preiser Scientific - Catalog #17-8360 or equal)
18	2	Propipette Bulbs
19	1	Filter photometer, AC, Hach or equivalent (Hach No. 110400, 115 V, 60 Hz) with capabilities for iron, manganese, fluoride (SPADNS) method, Nitrate (cadmium reduction), with necessary reagents.
20	1	Specific ion meter - expanded scale millivolt capability, readable and accurate to 0.1 millivolt. Instruments meeting the specifications of the Orion model 407 A, the Orion model 801 A, the Corning model 110, or equivalent are satisfactory, complete with specific ion electrodes. FLUORIDE ANALYSIS REQUIRED ONLY FOR THOSE SUPPLIES FLUORIDATING.
21	1	Automatic Batch Fluoride still, Hach or equivalent, Hach Catalog #592. NOTE: If the SPADNS colorimetric method for fluoride is used, all samples must be distilled before this determination is made. If the specific ion electrode method is used (as mentioned in item #20 above), this piece of equipment can be omitted.
22	1	Stirring apparatus for "jar test", 6 unit, with variable speed control and light reflector.
23		Chemical Supplies:
	32 oz.	Sulfuric Acid, N/50 solution
	32 oz.	Sodium Hydroxide, N/44 solution
	16 oz.	Methyl Orange indicator solution
	16 oz.	Phenolphthalein indicator solution
	8 oz.	Sodium Arsenite reagent
	16 oz.	Buffer Hardness reagent
	2 vials	Hardness indicator powder (EDTA)
	32 oz.	Hardness Reagent (titrating)
	32 oz.	SPADNS Reagent
	16 oz.	Fluoride solution, standard 1.0 ppm
	1 gal.	TISAB (for use with specific ion electrode

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Item Number	Quantity	Items
23 cont.		method for fluoride analysis).
	1 pint	pH Buffer 7.0
	1 pint	pH Buffer 4.0

LABORATORY FACILITIES - General Notes

1. Adequate laboratory space should be made available. As a guideline, there should be approximately 150 to 200 square feet per person, regardless of test, and approximately 15 linear feet of usable bench space including a sink with hot and cold water taps.

2. Raw and post-settling water taps should be provided in the laboratory area for quality control monitoring.

3. Sufficient electrical outlets must be provided for operating the laboratory equipment.

4. GLASSWARE - all glassware purchased for laboratory use should be composed of PYREX or KIMAX type glass. This type of glass is more resistant to damage by heat, chemicals, and abuse than is regular soft glass. All volumetric glassware should be marked CLASS A, denoting that it meets federal specifications for volumetric glassware, and need not be calibrated before use.